SF File Number
11.5

The RETEC Group, Inc.
1726 Cole Boulevard
Building 22, Suite 150
Golden, CO 80401-3213

303.271. 2100 Phone
303.277. 0110 Fax
www.retec.com

MEMORANDUM

TO: Jim Harris
Dave Smith

FROM: Chris Cosentini
Maureen Conorozzo
Mark Westray

DATE: April 12, 2006

RE: Evaluation of Natural Attenuation and Biodegradation Assimilative Capacity for the Somers Former Tie-Treating Plant

---

Overview

An evaluation of the assimilative capacity of the aquifer at the former BNSF Tie Treating Plant, in Somers, Montana to naturally degrade dissolved phase creosote constituents in groundwater was conducted using the approach outlined in the memo of December 14, 2005. This evaluation was conducted at the request of EPA, following approval of the technical impracticability waiver and submittal of the "Draft Request to Modify Groundwater Treatment System" (RETEC, 2004). The evaluation used the screening methodology described in USEPA's document, BIOSCREEN Natural Attenuation Decision Support System, User's Manual Version 1.3 (Newell, C.J. et al, 1996). The calculations were performed to estimate the rate of naphthalene biodegradation occurring under ambient conditions. Data used in calculations were obtained from groundwater samples collected February 13-14, 2006 and analyzed for natural attenuation parameters, including electron acceptors (dissolved oxygen, nitrate, and sulfate) and metabolic by-products (ferrous iron and methane).

Approach and Assumptions

Wells at the site were classified as upgradient, source zone, or downgradient based on groundwater flow direction and past analytical data. Wells in each classification are shown with different color/symbol codes on the potentiometric surface map (Figure 1). Upgradient wells can be grouped based on location into the western group (S-85-3, S-84-11, and S-4) and the eastern group (S-85-8B, S-85-8A, S-88-8C, and S-85-7). Well S-95-1 was not sampled. Wells in the western group were not used for the assimilative capacity calculations because of their relative distance from the source area and because they do not appear to be on a direct flow path to the source area wells. Only upgradient wells in the eastern group were included in the calculations. Well S-84-15 was sampled as a downgradient well. Upon evaluation of the sample results and the screened interval of the wells it was determined that this well is screened at the upper surface of the aquifer and does not represent the creosote impacted aquifer. Consequently data from S-84-15 was not used in the evaluation. All analytical results from the February 2006 sampling are presented in Table 1.

Data evaluation and assimilative capacity calculations were performed based on three scenarios:

- **Best Estimate.** This scenario best represents actual site conditions, based on available data. The average electron acceptor concentrations for upgradient and source zone wells and the average metabolic byproduct concentrations for source zone wells were used in the assimilative capacity calculations. The saturated thickness used for this scenario was 71 feet (ft), which is a relatively conservative value since the deepest well at the site contacted bedrock at 91 ft below ground surface (bgs). The hydraulic gradient used was 0.0035 ft/ft, which is in the middle of the measured range of hydraulic gradients at the site.

- **Conservative (low-biased).** This scenario is based on the use of parameter values that would result in the calculation of the lowest possible assimilative capacity. The depletion of electron acceptors was calculated from the lowest measured electron acceptor concentrations in upgradient wells and the highest electron acceptor concentrations in source area wells. Metabolic byproduct production was based on the lowest of the measured byproduct concentrations in source area wells. A highly conservative rate of groundwater flux was derived using a saturated thickness value of 61 ft, the approximate depth of the treatment system injection and extraction wells, and a hydraulic gradient of 0.002 ft/ft, which is the low end of the measured range of hydraulic gradients at the site.

- **Best Case (high-biased).** This scenario represents the best case, or highest possible assimilative capacity, based on available data. The highest measured electron acceptor concentrations for upgradient wells and the lowest measured electron acceptor and highest measured metabolic byproduct concentrations for source zone wells were used in calculations. The saturated thickness used was 91 ft, which is the depth to bedrock in the deepest well at the site. The hydraulic gradient used was 0.005 ft/ft, which is the high end of the measured range of hydraulic gradients at the site.

The hydraulic conductivity was assumed to be 0.35 ft/day for all scenarios, which is based on previous studies at the site and is consistent with expected values based on site geology. The site width was estimated to be 600 ft for all scenarios. The dissolved oxygen concentration for well S93-2D was not used because it is anomalously high compared to values measured in the other source zone wells. The reporting limit concentration was used for any non-detect values.

The assimilative capacity (biodegradation capacity) calculation used for this evaluation requires a utilization factor for each electron acceptor or metabolic byproduct used. These utilization factors are calculated based on the stoichiometric ratio of electron acceptor consumed or metabolic byproduct generated to the mass of dissolved hydrocarbon degraded in the biodegradation reactions. The BIOSCREEN Manual lists utilization factors for degradation of

combined BTEX constituents. Based on stoichiometric relationships, these utilization factors were multiplied by 0.955 to obtain utilization factors for naphthalene degradation.

Evaluation Methods

The BIOSCREEN Model is based on the assumption that biodegradation reactions are relatively instantaneous in comparison to the time required for electron acceptors to be replenished under normal groundwater flow conditions. If this assumption is valid, electron acceptor concentrations should be lower in the source zone than upgradient, and metabolic byproduct concentrations should be higher in the source zone than upgradient. This assumption was tested against site data by graphing the average upgradient, source zone, and downgradient concentrations of the electron acceptors and metabolic byproducts. As shown in Figure 2, the instantaneous reaction assumption is valid for the evaluated data because the electron acceptor concentrations are lower and the metabolic byproduct concentrations are higher in the source and downgradient zones as compared to upgradient.

The assimilative capacity calculations were performed using the spreadsheet presented in the memo of December 14, 2005 (Table 2). To obtain the total assimilative capacity of the aquifer to biodegrade naphthalene the spreadsheet is configured as follows:

- The amount of available electron acceptors is calculated by taking the difference between upgradient and source zone concentrations of oxygen, nitrate, and sulfate. Similarly, the production of metabolic byproducts is based on the observed source-zone concentrations of methane and ferrous iron.

- The concentration of each electron acceptor or metabolic byproduct is converted to a flux by multiplying by the groundwater flux (calculated with Darcy's Law using aquifer parameters: site width, saturated thickness, hydraulic conductivity, and hydraulic gradient).

- Each electron acceptor/metabolic byproduct flux is divided by its utilization factor for naphthalene to obtain an individual biodegradation assimilative capacity for that constituent.

- The individual biodegradation assimilative capacities are added together to obtain a total assimilative capacity for the aquifer. Values of zero were used for any negative values.

These assimilative capacity calculations were conducted for each of the three scenarios discussed above and are presented in Tables 3a, 3b, and 3c.

RETEC

Additional Downgradient Assimilative Capacity

The assimilative capacity calculations presented in Tables 3a, 3b, and 3c are based on the flux of electron acceptors and metabolic byproducts between the upgradient wells and the source zone. As shown in Figure 2, methane and ferrous iron concentrations are higher downgradient than in the source zone, and electron acceptor concentrations change very little between the source zone and downgradient. This is evidence that biodegradation, particularly through methanogenesis and iron reduction, is continuing to occur in the downgradient wells. Therefore, calculations were performed to quantify the additional assimilative capacity resulting from constituent biodegradation in the portion of the aquifer between the source area and the downgradient wells. These calculations were performed in essentially the same manner as previously described to determine best estimate, conservative, and best case assimilative capacity within the aquifer downgradient from the source area. For these calculations, the difference in the average concentrations of metabolic byproducts and electron acceptors in the downgradient zone compared to the source zone. The evaluated scenarios are summarized as follows:

- **Best Estimate.** This scenario best represents actual site conditions, based on available data. The average electron acceptor and metabolic byproduct concentrations for source zone and downgradient wells were used in the assimilative capacity calculations.

- **Conservative (low-biased).** This scenario is based on the use of parameter values that would result in the calculation of the lowest possible assimilative capacity over the entire site. The depletion of electron acceptors was calculated from the highest measured electron acceptor concentrations in source zone wells and the highest electron acceptor concentrations in downgradient wells. Metabolic byproduct production was based on the lowest of the measured byproduct concentrations in source area wells and the lowest measured byproduct concentrations in the downgradient wells.

- **Best Case (high-biased).** This scenario represents the best case, or highest possible assimilative capacity, based on available data, over the entire site. The lowest measured electron acceptor concentrations for source area wells and the lowest measured electron acceptor concentrations for downgradient wells were used. The highest measured metabolic byproduct concentrations for source zone wells and the highest measured metabolic byproduct concentrations for downgradient wells were used in calculations.

The calculations of additional assimilative capacity for each scenario, based on the flux of electron acceptors and metabolic byproducts between the source zone and downgradient wells, are presented in Tables 4a, 4b, and 4c.

RETEC

Results

A summary of the calculation inputs and resulting total assimilative capacity for each scenario is given in Table 5. The calculated total assimilative capacity for the best estimate scenario is 48,547 milligrams per day (mg/day) or 39 pounds per year (lb/year), with 33,838 mg/day (27lb/year) from the upgradient/source zone flux and 14,709 mg/day (12 lb/year) from the source zone/downgradient flux. Calculated total assimilative capacity for the conservative scenario is 12,800 mg/day (10 lb/year), with 5,527 mg/day (4 lb/year) from the upgradient/source zone flux and 7,273 mg/day (6 lb/year) from the source zone/downgradient flux. Total assimilative capacity for the best case scenario is 121,078 mg/day (97 lb/year), with 93,942 mg/day (76 lb/year) from the upgradient/source zone flux and 27,136 mg/day (22 lb/year) from the source zone/downgradient flux. The calculations indicate that methanogenesis is the predominant biodegradation pathway, accounting for 90 to 98 percent of the total assimilative capacity.

This analysis indicates that natural attenuation processes at the site constitute a significant mechanism for dissolved phase creosote constituent removal. The range of values calculated for natural attenuation processes is within the same order of magnitude of the observed removal achieved by the groundwater extraction and treatment system. During the last three years of treatment system operation, naphthalene removal has ranged from less than one pound per year to 34 pounds per year. Consequently, it seems appropriate to suspend operation of the extraction and treatment system and implement a program of monitored natural attenuation (MNA) as a more effective remedial alternative for the long-term mitigation of groundwater impacts at the site.

Table 1
Analytical Results
February 13-14, 2006
Former BNSF Tie Treating Plant
Somers, Montana

Analyte	Type	Upgradient											
	Well	West S-4	West S-4 DUP	West S-84-11	West S-85-3	East S-85-8B	East S-85-8A	East S-88-8C	East S-85-7	Average	S-88-2	S93-3	S93-2S
	Units												
Carbon monoxide	mg/L	--	--	--	--	1 U	--	--	--		1 U	1 U	1 U
Carbon dioxide	mg/L	84	100	110	69	3.6 J	71	17	4.5 J	24.03	100	170	180
Nitrogen	mg/L	19	19	20	22	21	16	18	21	19.00	8.1	4.5	4.4
Oxygen	mg/L	4.3	2.7	3.3	3.5	2.9	2.3	3	2.8	2.75	1.8	0.45 J	0.59
Methane	ug/L	0.35	0.66	0.33	5.1	440	18000	1000	58	4874.50	16000	23000	19000
Nitrate	mg/L	9.3	9.2	11	0.9	2.3	0.5 U	0.5 U	3	1.58	0.5 U	0.5 U	0.5 U
Sulfate	mg/L	250	260	85	200	6.9	3.9	2.8	8.8	5.60	3	3.5	3.4
Ferrous Iron	mg/L	0.3 J	1 U	4.9	3.3	1 U	16	0.7 J	1 U	4.68	1.7	12	12
Total Suspended Solids(TSS)	mg/L	10 J	7 J	5 J	14	23	530	10 U	17	145.00	30	60	33

Notes:

Shaded cells indicate data that was not used for assimilative capacity calculations

Detected values are shown in bold type

mg/L = milligrams per liter

ug/L = micrograms per liter

U = analyte not detected, value shown is the reporting limit

J = analyte detected, estimated value

Table 1(continued)
Analytical Results
February 13-14, 2006
Former BNSF Tie Treating Plant
Somers, Montana

Analyte	Type	Source Zone				Downgradient					
	Well	S93-2D	S-88-1	S-93-5S	Average	S-85-6B	S-85-6A	S-88-3	S91-2	S84-15	Average
	Units										
Carbon monoxide	mg/L	1 U	1 U	1 U		--	--	--	1 U	1 U	
Carbon dioxide	mg/L	100	180	60	131.67	90	140	61	150	61	110.25
Nitrogen	mg/L	12	3.6	16	8.10	8.9	3	11	5.6	20	7.125
Oxygen	mg/L	6.2	0.28 J	0.66	0.76	2.4	0.38 J	0.91	0.39 J	5.4	1.02
Methane	ug/L	11000	20000	5500	15750.00	24000	29000	12000	25000	34	22500
Nitrate	mg/L	0.9	0.5 U	0.9	0.63	0.5 U	0.5 U	0.9	0.5 U	1.5	0.6
Sulfate	mg/L	3	2.8	8.3	4.00	2.8	2.8	2.9	2.8	190	2.825
Ferrous Iron	mg/L	7	16	0.4 J	8.18	9.4	56	1.2	13	1 U	19.9
Total Suspended Solids(TSS)	mg/L	29	230	100	80.33	33	110	44	37	5 J	56

Notes:

Shaded cells indicate data that was not used fo

Detected values are shown in bold type

mg/L = milligrams per liter

ug/L = micrograms per liter

U = analyte not detected, value shown is the re

J = analyte detected, estimated value

Table 2
Biodegradation Capacity Evaluation
Former BNSF Tie Treating Plant
Somers, Montana

Aquifer Data	Oxygen Flux	Nitrate Flux	Ferrous Iron Flux	Sulfate Flux	Methane Flux	
Width of Site (ft)	1200 ft					
Aquifer Thickness (ft)	50 ft					
Hydraulic Conductivity (K) (ft/d)	0.35 ft/d					
Gradient (i) (ft/ft)	0.005					
Upgradient Oxygen Conc. (mg/L)	0 mg/L	delta NO_3 0 mg/L	delta Fe+2 0 mg/L	delta SO_4 0 mg/L	delta CH_4 0 mg/L	
Upgradient Oxygen Conc. (mg/m^3)	0 mg/m^3	0 mg/m^3	0 mg/m^3	0 mg/m^3	0 mg/m^3	
Q=KiA (ft^3/d)	105 ft^3/d					
Q=KiA (m^3/d)	2.97 m^3/d					
Flux of Oxygen [upgradient or delta * Q (in m^3/d)]	0 mg/d	NO_3 Flux 0 mg/d	Fe+2 Flux 0 mg/d	SO_4 Flux 0 mg/d	CH_4 Flux 0 mg/d	
Biodegradation Assimilative Capacity [Flux/utilization factor]	0 mg/d	0 mg/d	0 mg/d	0 mg/d	0 mg/d	
Ambient Naphthalene Biodegradation Capacity (mg/d)	0 mg/d	0 mg/d	0 mg/d	0 mg/d	0 mg/d	**Total Assimilative Capacity 0 mg/d**

Notes:

Naphthalene Utilization Factors*	mg/L	mg/m^3
Oxygen	3.00	3,000
Nitrate	4.68	4,680
Ferrous Iron	20.8	20,820
Sulfate	4.49	4,490
Methane	0.74	740

* = Based on BTEX utilization factor (from BIOSCREEN) corrected for naphthalene by multiplying by 0.955 (or 95.5% of the BTEX utilization factor)

Table 3a
Biodegradation Capacity Evaluation - Best Estimate Calculation
Upgradient to Source Zone Evaluation
Former BNSF Tie Treating Plant
Somers, Montana

Aquifer Parameters	Oxygen Flux	Nitrate Flux	Ferrous Iron Flux	Sulfate Flux	Methane Flux	
Width of Site (ft)	600 ft					
Aquifer Thickness (ft)	71 ft					
Hydraulic Conductivity (K) (ft/d)	0.35 ft/d					
Gradient (i) (ft/ft)	0.0035					
Delta Oxygen Conc. (mg/L)	1.994 mg/L	delta NO_3 0.9417 mg/L	Source Fe^{+2} 8.18333 mg/L	delta SO_4 1.6 mg/L	Source CH_4 15.75 mg/L	
Delta Oxygen Conc. (mg/m^3)	1994 mg/m^3	941.67 mg/m^3	8183.33 mg/m^3	1600 mg/m^3	15750 mg/m^3	
Q=KiA (ft^3/d)	52.185 ft^3/d					
Q=KiA (m^3/d)	1.48 m^3/d					
Flux of Oxygen [upgradient or delta * Q (in m^3/d)]	2947 mg/d	NO_3 Flux 1392 mg/d	Fe^{+2} Flux 12093 mg/d	SO_4 Flux 2364.3562 mg/d	CH_4 Flux 23274.132 mg/d	
Biodegradation Assimilative Capacity [Flux/utilization factor]	982 mg/d	297 mg/d	581 mg/d	527 mg/d	31452 mg/d	
Ambient Naphthalene Biodegradation Capacity (mg/d)	982 mg/d	297 mg/d	581 mg/d	527 mg/d	31,452 mg/d	**Total Assimilative Capacity 33,838 mg/d**

Notes:

Naphthalene Utilization Factors*	mg/L	mg/m^3
Oxygen	3.00	3,000
Nitrate	4.68	4,680
Ferrous Iron	20.8	20,820
Sulfate	4.49	4,490
Methane	0.74	740

* = Based on BTEX utilization factor (from BIOSCREEN) corrected for naphthalene by multiplying by 0.955 (or 95.5% of the BTEX utilization factor)

Table 3b
Biodegradation Capacity Evaluation - Conservative (Low-biased) Estimate Calculation
Upgradient to Source Zone Evaluation
Former BNSF Tie Treating Plant
Somers, Montana

Aquifer Parameters	Oxygen Flux	Nitrate Flux	Ferrous Iron Flux	Sulfate Flux	Methane Flux	
Width of Site (ft)	600 ft					
Aquifer Thickness (ft)	61 ft					
Hydraulic Conductivity (K) (ft/d)	0.35 ft/d					
Gradient (i) (ft/ft)	0.002					
Delta Oxygen Conc. (mg/L)	0.5 mg/L	delta NO_3 -0.4 mg/L	Source Fe^{+2} 0.4 mg/L	delta SO_4 -5.5 mg/L	delta CH_4 5.5 mg/L	
Delta Oxygen Conc. (mg/m^3)	500 mg/m^3	-400 mg/m^3	400 mg/m^3	-5500 mg/m^3	5500 mg/m^3	
Q=KiA (ft^3/d)	25.62 ft^3/d					
Q=KiA (m^3/d)	0.73 m^3/d					
Flux of Oxygen [upgradient or delta * Q (in m^3/d)]	363 mg/d	NO_3 Flux -290 mg/d	Fe^{+2} Flux 290 mg/d	SO_4 Flux -3990.148 mg/d	CH_4 Flux 3990.1485 mg/d	
Biodegradation Assimilative Capacity [Flux/utilization factor]	121 mg/d	-62 mg/d	14 mg/d	-889 mg/d	5392 mg/d	
Ambient Naphthalene Biodegradation Capacity (mg/d)	121 mg/d	(62) mg/d	14 mg/d	(889) mg/d	5,392 mg/d	**Total Assimilative Capacity 5,527 mg/d**

Notes:

Naphthalene Utilization Factors*	mg/L	mg/m^3
Oxygen	3.00	3,000
Nitrate	4.68	4,680
Ferrous Iron	20.8	20,820
Sulfate	4.49	4,490
Methane	0.74	740

* = Based on BTEX utilization factor (from BIOSCREEN) corrected for naphthalene by multiplying by 0.955 (or 95.5% of the BTEX utilization factor)

Table 3c
Biodegradation Capacity Evaluation - Best-case (High-biased) Estimate Calculation
Upgradient to Source Zone Evaluation
Former BNSF Tie Treating Plant
Somers, Montana

Aquifer Parameters	Oxygen Flux	Nitrate Flux	Ferrous Iron Flux	Sulfate Flux	Methane Flux	
Width of Site (ft)	600 ft					
Aquifer Thickness (ft)	91 ft					
Hydraulic Conductivity (K) (ft/d)	0.35 ft/d					
Gradient (i) (ft/ft)	0.005					
Delta Oxygen Conc. (mg/L)	3 mg/L	delta NO_3 2.5 mg/L	Source Fe^{+2} 16 mg/L	delta SO_4 6 mg/L	delta CH_4 23 mg/L	
Delta Oxygen Conc. (mg/m^3)	3000 mg/m^3	2500 mg/m^3	16000 mg/m^3	6000 mg/m^3	23000 mg/m^3	
Q=KiA (ft^3/d)	95.55 ft^3/d					
Q=KiA (m^3/d)	2.71 m^3/d					
Flux of Oxygen [upgradient or delta * Q (in m^3/d)]	8117 mg/d	NO_3 Flux 6764 mg/d	Fe^{+2} Flux 43291 mg/d	SO_4 Flux 16234.136 mg/d	CH_4 Flux 62230.855 mg/d	
Biodegradation Assimilative Capacity [Flux/utilization factor]	2706 mg/d	1445 mg/d	2079 mg/d	3616 mg/d	84096 mg/d	
Ambient Naphthalene Biodegradation Capacity (mg/d)	2,706 mg/d	1,445 mg/d	2,079 mg/d	3,616 mg/d	84,096 mg/d	**Total Assimilative Capacity** **93,942 mg/d**

Notes:

Naphthalene Utilization Factors*	mg/L	mg/m^3
Oxygen	3.00	3,000
Nitrate	4.68	4,680
Ferrous Iron	20.8	20,820
Sulfate	4.49	4,490
Methane	0.74	740

* = Based on BTEX utilization factor (from BIOSCREEN) corrected for naphthalene by multiplying by 0.955 (or 95.5% of the BTEX utilization factor)

Table 4a
Additional Biodegradation Capacity Evaluation - Best Estimate Calculation
Source Zone to Downgradient Evaluation
Former BNSF Tie Treating Plant
Somers, Montana

Aquifer Parameters	Oxygen Flux	Nitrate Flux	Ferrous Iron Flux	Sulfate Flux	Methane Flux	
Width of Site (ft)	600 ft					
Aquifer Thickness (ft)	71 ft					
Hydraulic Conductivity (K) (ft/d)	0.35 ft/d					
Gradient (i) (ft/ft)	0.0035					
Delta Oxygen Conc. (mg/L)	-0.26 mg/L	delta NO_3 0.03 mg/L	Source Fe^{+2} 11.72 mg/L	delta SO_4 1.18 mg/L	Source CH_4 6.75 mg/L	
Delta Oxygen Conc. (mg/m^3)	-260 mg/m^3	30 mg/m^3	11720 mg/m^3	1180 mg/m^3	6750 mg/m^3	
Q=KiA (ft^3/d)	52.185 ft^3/d					
Q=KiA (m^3/d)	1.48 m^3/d					
Flux of Oxygen [upgradient or delta * Q (in m^3/d)]	-384 mg/d	NO_3 Flux 44 mg/d	Fe^{+2} Flux 17319 mg/d	SO_4 Flux 1743.7127 mg/d	CH_4 Flux 9974.6279 mg/d	
Biodegradation Assimilative Capacity [Flux/utilization factor]	-128 mg/d	9 mg/d	832 mg/d	388 mg/d	13479 mg/d	
Ambient Naphthalene Biodegradation Capacity (mg/d)	(128) mg/d	9 mg/d	832 mg/d	388 mg/d	13,479 mg/d	**Total Assimilative Capacity 14,709 mg/d**

Notes:

Naphthalene Utilization Factors*	mg/L	mg/m^3
Oxygen	3.00	3,000
Nitrate	4.68	4,680
Ferrous Iron	20.8	20,820
Sulfate	4.49	4,490
Methane	0.74	740

* = Based on BTEX utilization factor (from BIOSCREEN) corrected for naphthalene by multiplying by 0.955 (or 95.5% of the BTEX utilization factor)

Table 4b
Additional Biodegradation Capacity Evaluation - Conservative (Low-biased) Estimate Calculation
Source Zone to Downgradient Evaluation
Former BNSF Tie Treating Plant
Somers, Montana

Aquifer Parameters	Oxygen Flux	Nitrate Flux	Ferrous Iron Flux	Sulfate Flux	Methane Flux	
Width of Site (ft)	600 ft					
Aquifer Thickness (ft)	61 ft					
Hydraulic Conductivity (K) (ft/d)	0.35 ft/d					
Gradient (i) (ft/ft)	0.002					
Delta Oxygen Conc. (mg/L)	-0.6 mg/L	delta NO_3 0 mg/L	delta Fe^{+2} 0.8 mg/L	delta SO_4 5.4 mg/L	delta CH_4 6.5 mg/L	
Delta Oxygen Conc. (mg/m^3)	-600 mg/m^3	0 mg/m^3	800 mg/m^3	5400 mg/m^3	6500 mg/m^3	
Q=KiA (ft^3/d)	25.62 ft^3/d					
Q=KiA (m^3/d)	0.73 m^3/d					
Flux of Oxygen [upgradient or delta * Q (in m^3/d)]	-435 mg/d	NO_3 Flux 0 mg/d	Fe^{+2} Flux 580 mg/d	SO_4 Flux 3917.6003 mg/d	CH_4 Flux 4715.63 mg/d	
Biodegradation Assimilative Capacity [Flux/utilization factor]	-145 mg/d	0 mg/d	28 mg/d	873 mg/d	6372 mg/d	
Ambient Naphthalene Biodegradation Capacity (mg/d)	(145) mg/d	0 mg/d	28 mg/d	873 mg/d	6,372 mg/d	**Total Assimilative Capacity 7,273 mg/d**

Notes:

Naphthalene Utilization Factors*	mg/L	mg/m^3
Oxygen	3.00	3,000
Nitrate	4.68	4,680
Ferrous Iron	20.8	20,820
Sulfate	4.49	4,490
Methane	0.74	740

* = Based on BTEX utilization factor (from BIOSCREEN) corrected for naphthalene by multiplying by 0.955 (or 95.5% of the BTEX utilization factor)

Table 4c
Additional Biodegradation Capacity Evaluation - Best-case (High-biased) Estimate Calculation
Source Zone to Downgradient Evaluation
Former BNSF Tie Treating Plant
Somers, Montana

Aquifer Parameters	Oxygen Flux	Nitrate Flux	Ferrous Iron Flux	Sulfate Flux	Methane Flux	
Width of Site (ft)	600 ft					
Aquifer Thickness (ft)	91 ft					
Hydraulic Conductivity (K) (ft/d)	0.35 ft/d					
Gradient (i) (ft/ft)	0.005					
Delta Oxygen Conc. (mg/L)	-0.1 mg/L	delta NO_3 0 mg/L	delta Fe^{+2} 40 mg/L	delta SO_4 0 mg/L	delta CH_4 6 mg/L	
Delta Oxygen Conc. (mg/m^3)	-100 mg/m^3	0 mg/m^3	40000 mg/m^3	0 mg/m^3	6000 mg/m^3	
Q=KiA (ft^3/d)	95.55 ft^3/d					
Q=KiA (m^3/d)	2.71 m^3/d					
Flux of Oxygen [upgradient or delta * Q (in m^3/d)]	-271 mg/d	NO_3 Flux 0 mg/d	Fe^{+2} Flux 108228 mg/d	SO_4 Flux 0 mg/d	CH_4 Flux 16234.136 mg/d	
Biodegradation Assimilative Capacity [Flux/utilization factor]	-90 mg/d	0 mg/d	5198 mg/d	0 mg/d	21938 mg/d	
Ambient Naphthalene Biodegradation Capacity (mg/d)	(90) mg/d	0 mg/d	5,198 mg/d	0 mg/d	21,938 mg/d	**Total Assimilative Capacity 27,136 mg/d**

Notes:

Naphthalene Utilization Factors*	mg/L	mg/m^3
Oxygen	3.00	3,000
Nitrate	4.68	4,680
Ferrous Iron	20.8	20,820
Sulfate	4.49	4,490
Methane	0.74	740

* = Based on BTEX utilization factor (from BIOSCREEN) corrected for naphthalene by multiplying by 0.955 (or 95.5% of the BTEX utilization factor)

Table 5
Biodegradation Assimilative Capacity Evaluation Summary
Former BNSF Tie Treating Plant
Somers, Montana

Calculation Inputs		Best Estimate		Conservative (Low-Biased) Estimate		Best-Case (High-Biased) Estimate	
		Upgradient to Source	Source to Downgradient	Upgradient to Source	Source to Downgradient	Upgradient to Source	Source to Downgradient
Aquifer Parameters	Width of Site (ft)	600	600	600	600	600	600
	Aquifer Thickness (ft)	71	71	61	61	91	91
	Hydraulic Conductivity (K) (ft/d)	0.35	0.35	0.35	0.35	0.35	0.35
	Gradient (i) (ft/ft)	0.0035	0.0035	0.002	0.002	0.005	0.005
Electron Acceptor Concentrations	Delta Oxygen (mg/L)	1.99	-0.26	0.5	-0.6	3	-0.1
	Delta Nitrate (mg/L)	0.94	0.03	-0.4	0	2.5	0
	Delta Sulfate (mg/L)	1.6	1.18	-5.5	5.4	6	0
Metabolic By-product Concentrations	Source/Delta Ferrous Iron (mg/L)	8.18	11.72	0.4	0.8	16	40
	Source/Delta Methane (mg/L)	15.75	6.75	5.5	6.5	23	6
Subtotals (mg/d)		33,838	14,709	5,527	7,273	93,942	27,136
Subtotals (lbs/yr)		27	12	4	6	76	22
Total Assimilative Capacity (mg/d) (Naphthalene Biodegradation Capacity)		48,547		12,800		121,078	
Total Assimilative Capacity (lb/yr) (Naphthalene Biodegradation Capacity)		39		10		97	

Notes:
ft = feet
ft/d = feet per day
ft/ft = feet per foot
mg/L = milligrams per liter
mg/d = milligrams per day
lb/yr = pounds per year

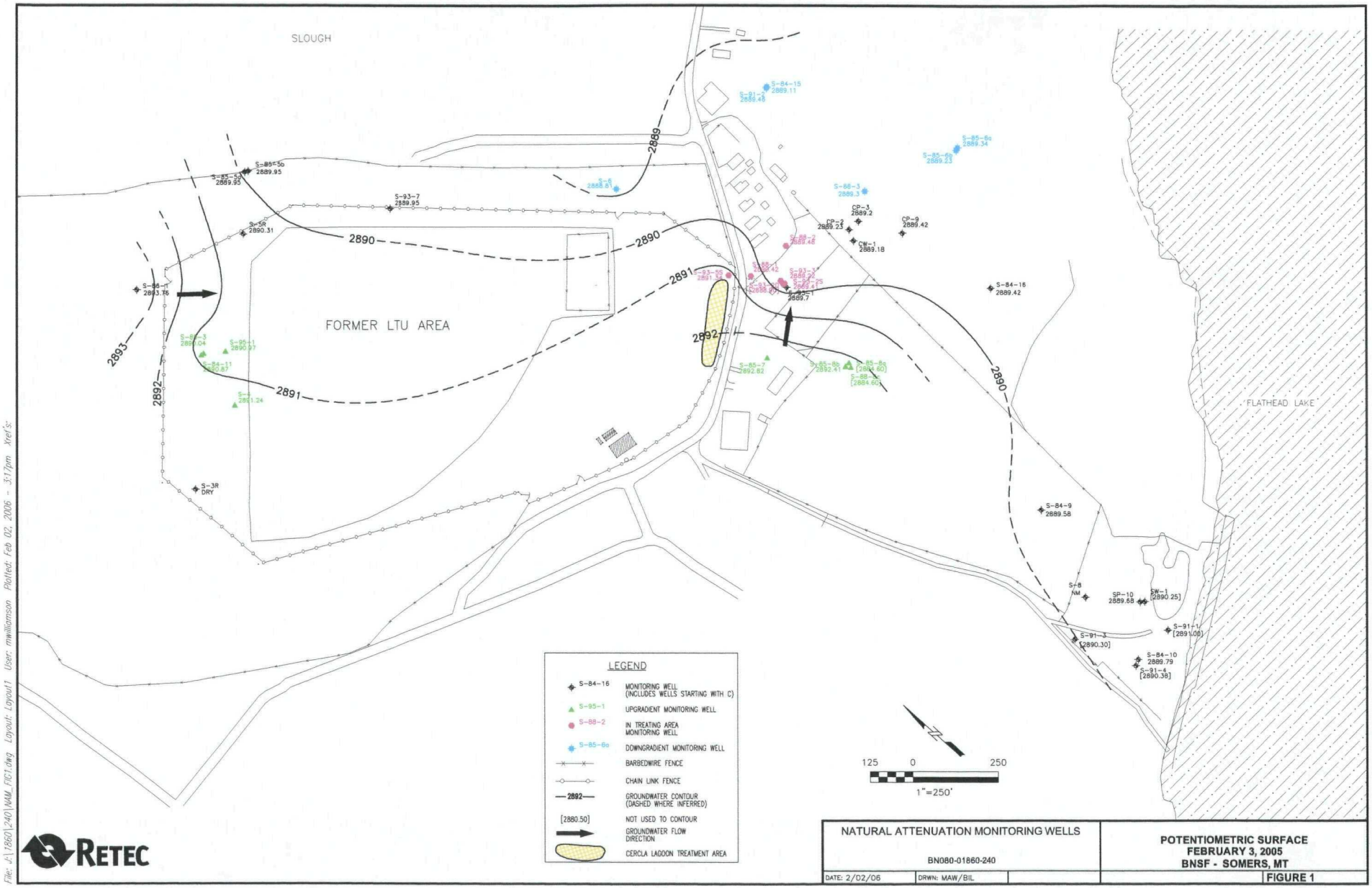
SLOUGH
FORMER LTU AREA
FLATHEAD LAKE
2889
2890
2891
2892
2893
S-84-15 2889.11
S-85-8a 2889.34
S-85-8b 2889.23
S-86-1 2889.3
CP-3 2889.2
CP-2 2889.23
CP-9 2889.42
CW-1 2889.18
S-88-1 2889.46
S-88-2 2889.42
S-84-16 2889.42
S-85-1 2889.7
S-85-5b 2889.95
S-85-5a 2889.95
S-93-7 2889.95
S-6 2888.81
S-5R 2890.31
S-96-1 2893.76
S-95-3 2891.04
S-95-1 2890.07
S-84-11 2890.87
S-4 2891.24
S-3R DRY
S-85-7 2892.82
S-85-8b 2892.41
S-85-8a [2884.60]
S-85-8c [2884.66]
S-84-9 2889.58
S-8 NM
SP-10 2889.68
SW-1 [2890.25]
S-91-1 [2891.08]
S-91-3 [2890.30]
S-84-10 2889.79
S-91-4 [2890.38]
125 0 250
1"=250'
LEGEND
S-84-16 MONITORING WELL (INCLUDES WELLS STARTING WITH C)
S-95-1 UPGRADIENT MONITORING WELL
S-88-2 IN TREATING AREA MONITORING WELL
S-85-8a DOWNGRADIENT MONITORING WELL
BARBEDWIRE FENCE
CHAIN LINK FENCE
2892 GROUNDWATER CONTOUR (DASHED WHERE INFERRED)
[2880.50] NOT USED TO CONTOUR
GROUNDWATER FLOW DIRECTION
CERCLA LAGOON TREATMENT AREA
RETEC
NATURAL ATTENUATION MONITORING WELLS
BN080-01860-240
DATE: 2/02/06
DRWN: MAW/BIL
POTENTIOMETRIC SURFACE
FEBRUARY 3, 2005
BNSF - SOMERS, MT
FIGURE 1
File: J:\1860\240\NAM_FIG1.dwg Layout: Layout1 User: mwilliamson Plotted: Feb 02, 2006 - 3:17pm Xref's:

Figure 2
Average Concentrations